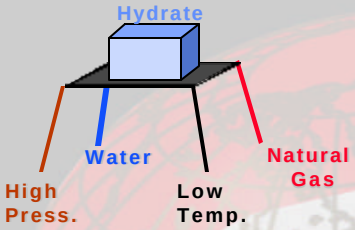
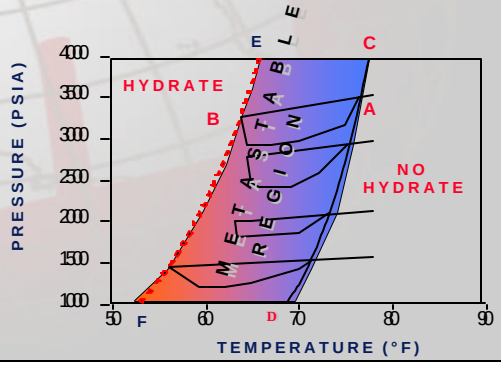
5. Puneet Sharma, Halliburton



Hydrates

Naturally Occurring
Forced Formation

Puneet Sharma
August 9, 2000



Hydrate Recovery

- Recovery of Natural Gas Hydrate
  - Gas hydrates abundant in nature
    - → Arctic regions
    - → Marine sediments

- Propose Method of mining, cleaning, and processing natural gas Hydrates on the seabed

- Potential Impact
  - Natural gas is a clean, efficient source of energy
  - Scientists believe hydrates contain more than twice as much energy as all the world's coal, oil and natural gas combined
  - Research in this area could position BRES and HES as the technology leaders for the next generation of energy sources

- Path Forward
  - A number of organizations are currently interested in this technology including DOD, DOE, Japan and India. Propose alliance with one or more organizations.

HALLIBURTON Brown & Root *Energy Services*

Forced Formation

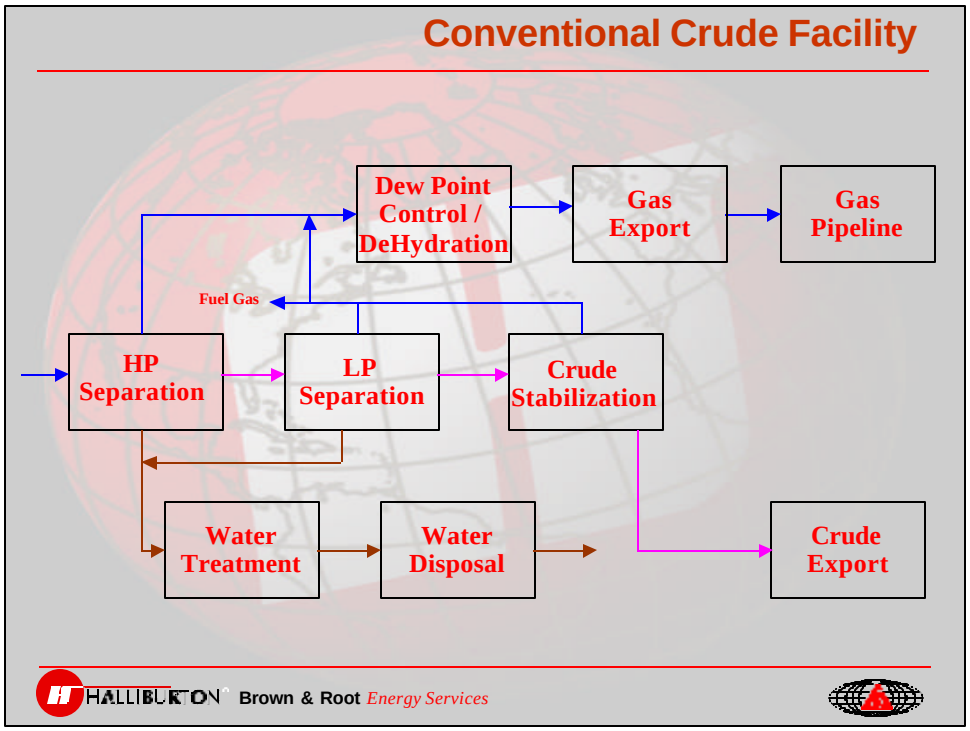
- Theoretical Concept
  - Conversion of Gas into a solid (Hydrate) in a controlled fashion
  - Transport Gas from Well-Head to "Refinery" as a Solid
- Example of Fields that meet Criteria
  - Alaska
  - Angola & Nigeria Developments
  - Caspian Developments (i.e. AIOC)
- Potential Area of Application - Field Development Constraints
  - Environmental Constraints
    - → Gas may not be flared
    - → Produced water may not be discharged overboard
  - Oil field with associated gas
    - → GOR: 500 -1000
    - → Oil Rate: Unlimited
    - → 30% water cut or seawater makeup is required

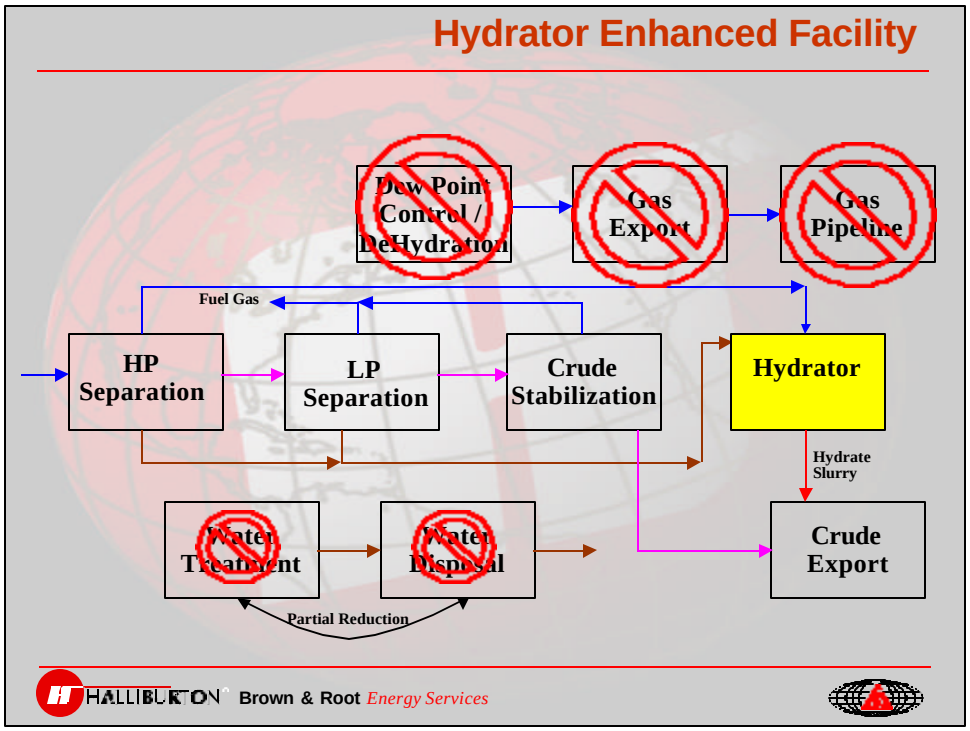
HALLIBURTON Brown & Root *Energy Services*

Forced Formation

- Potential Savings
  - Facilities
    - → Gas Compression
    - → Gas Dew Point Control
    - → Gas DeHydration
    - → Produced Water Treatment
    - → Produced Water Injection
  - Gas Export Pipeline
- Additional Items
  - "Hydrator"
  - Refrigeration
    - → Air and Seawater Exchangers
    - → Propane Refrigeration as necessary
  - Slurry Export Pumps instead of Normal Export Pumps
  - Slurry Handling at Terminal / Refinery
  - Hydrate dissolution at Refinery

HALLIBURTON Brown & Root *Energy Services*


Conventional Crude Facility
Dew Point Control / DeHydration
Gas Export
Gas Pipeline
Fuel Gas
HP Separation
LP Separation
Crude Stabilization
Water Treatment
Water Disposal
Crude Export
HALLIBURTON
Brown & Root Energy Services


Hydrator Enhanced Facility
Dew Point Control / DeHydration
Gas Export
Gas Pipeline
Fuel Gas
HP Separation
LP Separation
Crude Stabilization
Hydrator
Hydrate Slurry
Water Treatment
Water Disposal
Crude Export
Partial Reduction
HALLIBURTON
Brown & Root Energy Services

Product Development

- Stage 1 - Theoretical Issues
  - Hydration Batch or Continuous
  - Size versus throughput
  - Scalability
  - Conceptual Economics
- Stage 2 - Economic Issues
  - Comparison to other Technologies
    - → GTL & LNG
    - → Flaring & Re-Injection
  - How to unHydrate at Refinery?
  - Transport Methods?
  - Paper Model of Concept
  - Savings over conventional facility
- Stage 3 - Resolve Design Issues
  - Paper Design
  - Build Bench-Top Model
  - Test Theories
- Stage 4 - Test Scalability
  - Build Pilot Plant
  - Detail Design
- Stage 5 - Commercialize

HALLIBURTON Brown & Root *Energy Services*

Stage 1 Results

- Is Hydration Batch or Continuous?
  - Continuous
- Conditions Required for Reaction?
  - Residence time in Reactor?
    - → Catalyst
    - → Lower Temperature
    - → Higher Pressure
  - Hydrate Stability?
    - → Hydrate Agglomeration? - Conventional chemicals may be used to prevent Agglomeration. Research under way to develop said chemical
    - → Hydrates may be transported near 80F and 1000 psig using chemicals.
- Size relative to throughput?
  - Require Experiments
- Scalability?
  - Requires Experiments
- Conceptual Economics
  - CAPEX
    - → Depends on continuous phase
  - OPEX
    - → Fuel Gas Consumption - Papers suggest 15% consumption (incorrect)
    - → Transportation
      - Slurry Pipeline Possible
      - Tankers less expensive than LNG tankers; need 3 times as many
      - Trucks and Trains Illogical

HALLIBURTON Brown & Root *Energy Services*